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ABSTRACTS FROM THE FRENCH TECHNICAL PRESS.

Study of the Resistance Offered by Propellers Rotating on an Airstream.

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ABSTRACTS FROM THE FRENCH TECHNICAL PRESS.

STUDY OF THE RESISTANCE OFFERED BY PROPELLERS ROTATING IN AN AIRSTREAM.

The Parachutal Quality of Lifting Propellers.

We have shown by theoretical consideration, in a previous article* that the maximum thrust which could be furnished by a propeller rotating freely in an airstream was given by the following formula:

$$P = q^2 D^2 V^2 \qquad (1)$$

in which P represents the thrust, V the velocity of the airstream, D the diameter of the propeller, and q the lifting quality of a comparative propeller which we called a conjugate propeller. It must also be recollected that

$$q = \text{the ratio } \frac{\alpha^{\frac{3}{2}}}{\beta},$$

α and β being the usual coefficients of thrust and power.

In order to verify this data, we have had a complete series of tests executed at the Eiffel Laboratory on different propellers 80 cms. in diameter. These propellers could be braked to different speeds. By means of the device adopted, it was possible to measure the rotary speed, the velocity of the airflow, the brake torque and the thrust produced.

Six propellers were tested, their respective values as re-

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* "Aerophile," September 1 - 15, 1920, p.269.

gards the ratio of the pitch to the diameter being 0.2, 0.4, 0.6, 0.8, 1, and 1.2; they were composed of windmill vanes held by a hub.

The following tables give the principal results obtained in the case of four of these propellers. The velocity of rotation is estimated according to the number of revolutions per second, the thrust values are given in grams and the torque in gram-meters. Certain velocities in the tables have been plotted in Figs. 1 to 4. The numbers of revolutions being taken as abscissae, the thrusts and torques have been taken as ordinates, and the variations of these for each airstream velocity have thus been obtained.

TABLE I - Propeller I: $\frac{H}{D} = 1.$

V	N	P	C	q
16.85	0	772	48.3	0.13
	0.9	684	44.7	
	9.1	508	22.55	
	13.4	860	60.8	
	14.3	728	52.1	
	16.6	418	6.95	
18.50	0	939	58.3	0.103
	2.1	850	47.1	
	12.5	1070	80.6	
	15.5	984	65.7	
	16.9	895	42.2	
	18.3	498	7.69	
20	0	975	68.2	
	1.2	975	59.5	
	4.1	1165	50.8	
	15.1	1195	86.8	
	16.8	886	48.1	
	19.3	577	7.44	

TABLE I (Continued)

V	N	P	C	q
23	0	1370	89.3	
	1	1280	84.3	
	3.3	1280	69.0	
	17	1540	104.0	
	20	1235	68.2	
	21.6	705	6.2	
26.10	0	1770	119	
	2.8	1635	97.9	
	3.5	1680	93	
	21.2	1680	107	
	24.2	930	7.44	

TABLE II: $\frac{H}{D} = 0.6$ Propeller II

V	N	P	C	q
8.03	0	177	9.92	
	0.5	221	7.94	
	2.5	243	8.44	
	8.5	420	14.65	
	11.5	310	5.95	
10.70	0	357	16.9	0.136
	2.3	402	13.4	
	5	423	15.9	
	13.5	622	24.8	
	14	578	18.6	
	14.8	534	13.4	
	15.5	445	5.95	
13.10	0	459	25	0.116
	1	525	21.35	
	1.5	570	21.60	
	12	966	45.9	
	15.8	966	39.2	
	16.2	924	34	
	17.5	745	19.1	
	18	723	15.4	
	18.7	614	5.95	

TABLE II (Continued)

V	N	P	C	q
14.45	0	593	28	
	1	593	26	
	1.6	637	24.05	
	9.5	1035	37.2	
	12.5	1210	54.5	
	16.8	1170	47.6	
	17.7	1120	42.6	
	18	1035	38.4	
	19.3	945	25.3	
	20.6	725	6.2	
15.70	0	750	36	
	1.6	750	29.3	
	5	970	29.8	
	11	1470	49.6	
	15	1435	67.0	
	15.1	1410	61.3	
	18.3	1390	57	
	19.2	1320	50.9	
	19.6	1280	45.9	
	20.5	1150	33.5	
	22.5	882	6.45	

TABLE III. Propeller III: $\frac{H}{D} = 0.4$.

V	N	P	C	q
10.6	0	320	10.9	0.118
	3.3	452	7.44	
	16.7	850	10.35	
	18.5	717	6.20	
13.20	0	481	16.6	0.143
	7.5	924	14.15	
	18.3	1405	33.7	
	24.2	481	4.74	
14.60	0	549	19.85	
	8.3	1170	16.1	
15.90	0	705	22.05	
	1.6	705	19.35	
	21.6	1900	44.1	

TABLE IV: Propeller IV : $\frac{H}{D} = 0.2$

V	N	P	C	q
18	0 1.4 5.4	975 975 1370	18.1 11.9 6.45	
21.35	0 6.2 7.5	1320 1940 1985	22.6 8.68 7.69	0.085
25.40	0 9.1	1880 2870	32.35 9.92	
29.55	0 11.5 12.5	2550 3780 4000	47.1 10.2 9.92	

A close investigation of these tables and the following figures will show that the outline of the phenomenon varies in accordance with the size of the pitch of the propellers in question.

With propellers of large pitch (Figs. I and II), the thrust and torque attain a maximum almost simultaneously and then decrease to a minimum corresponding to the limit of the velocity that can be produced by the propeller.

The ascending branch of the curves corresponds to a regime that is unstable in so far as concerns its being impossible to regulate the tightening of the brake to maintain the propeller at one of the corresponding speeds of rotation; it constantly tends to slow down and stops completely, or, on the contrary, increases to reach the descending branch which corresponds to constant regimes.

In the case of propellers of very small pitch (see Fig. IV) the torque diminishes constantly while the thrust increases regularly. In addition to this, the speeds of rotation attained as a maximum by the propeller remain low even when the velocity of the airstream is high.

On considering the maximum thrust produced by propellers with different pitch, at the same airstream velocity, we find that:-

1. - The thrust is greater in proportion to the smallness of the pitch.

2. - The corresponding torque is proportionally lower when the pitch is smaller.

3. - The corresponding number of rotations is proportionally higher when the pitch is shorter.

Exception must be made, however, in the case of propellers of small pitch (Propeller IV) for which the thrust and number of rotations remain low even for high velocities of the airstream.

The conclusions to be drawn from these statements, as regards obtaining the maximum of thrust, that is, the maximum parachutal quality, are as follows:-

1. It is necessary that the pitch should be small, though not lower than a minimum of about 0.3 D.

2. The propeller must be braked in such a manner that its speed does not exceed a well determined value, corresponding to the maximum of thrust of the propeller.

These results may easily be compared with the theoretical results published in the note previously mentioned.

If we refer to the general formula $Tt = P V + T$, established in that note, and if we replace T by its value $\frac{P^{\frac{3}{2}}}{q D}$ deduced from Breguet's formula, we obtain:

$$Tt = P\,V + \frac{P^{\frac{3}{2}}}{q\,D}$$

or in its absolute value:

$$Tt = P\,V - \frac{P^{\frac{3}{2}}}{q\,D}$$

Tt, which is the work absorbed by the braking, is negative and V is negative; hence we get

$$V = \frac{Tt}{P} + \frac{P^{\frac{1}{2}}}{qD}$$

This shows that for a given value of P. weight of the airplane, the falling velocity is proportionally lower when Tt is smaller, and when q is greater, particularly when Tt = o, formula (1) is once more obtained:

$$P = q^2 D^2 V^2$$

Inversely, for a given value of V, the thrust P, that is, the weight that may be braked, is proportionally greater when q is greater and Tt is smaller.

It must be observed, however, that these parameters are not entirely independent one of the other.

In the case of a propeller of determined pitch, the variations of the braking torque modify the rotary speed and in so doing modify the angle of attack of each element, and consequently the quality depending on that angle.

The maximum thrust, in the case of propellers I, II, and III, therefore corresponds to a value of the braking torque which is not equal to zero. In the case of propeller IV, on the contrary, the thrust increases proportionally as the torque decreases.

If, however, the pitch of the propeller be altered, or to be more precise, if the blades be adjusted in a different direction, the incidence of each element is again modified and the quality is thus influenced.

Neither in one case nor the other can a determined incidence be given freely to each blade element; that is, the parameter q is not entirely independent.

It is therefore possible that the absolute maximum of thrust may not necessarily correspond to a braking torque = o when the adjustment of the blades and the braking torque are simultaneously altered. In order to elucidate this point, a new series of tests has been carried out; in these tests, at different velocities of the airstream (about 12 m.) the pitch was progressively varied, the propeller being entirely free to turn on its axis, and the degrees of thrust were noted down.

The maximum degrees of thrust correspond to a ratio of the pitch to the diameter = about 0.3, and the results obtained, - which are given in Table V, exceed the thrust produced by braked propellers with the same airstream velocities.

TABLE V.

V	α = 9s 40'	$\alpha = 8^{\circ}$	$\alpha = 6^{\circ}\ 30'$	$\alpha = 5^{\circ}$
6.00	256	324	The propeller does not rotate.	
8.13	429	489		
10.55	702	771	935	311
12.00	854	1079	1370	612
15.10	1320	1685	2075	1174

The formulas $V = \frac{Tt}{P} = \frac{P^{\frac{1}{2}}}{qD}$

$$P = q^2 \, D^2 \, V^2 \quad (\text{when } Tt = o)$$

enable us to make an easy calculation of the values of the parachutal quality of the propellers employed in each case, particularly in the case of the regimes which have given the maximum thrusts. The results of these calculations are given in the 5th column of the preceding tables.

The greatest values of q therefore correspond to propellers of large pitch. The values found are, moreover, far lower than the maximum theoretical quality, which is 0.63 (according to Colonel Renard); they are also lower than the values which may be obtained in practice and which are, according to Breguet, approximately 0.35.

Although this quality diminishes simultaneously with the pitch, advantage is none the less to be gained by utilizing propellers of small pitch, as they give the maximum of thrust by reason of the diminution of the braking torque. In the case of the propeller which gave the maximum thrust, among the propellers tested (see Table V), the parachutal quality was 0.12.

A certain number of considerations giving the theoretical explanation of these results will be presented in another article at an early date.

(Translated from the French by the Paris Office, N.A.C.A.)

THE PARACHUTAL QUALITY OF LIFTING PROPELLERS.

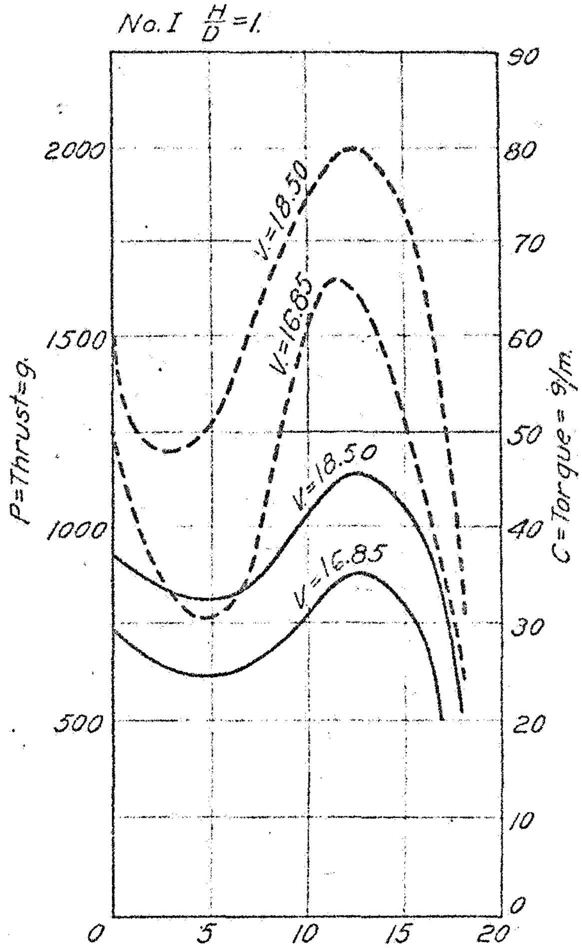

Fig. 1

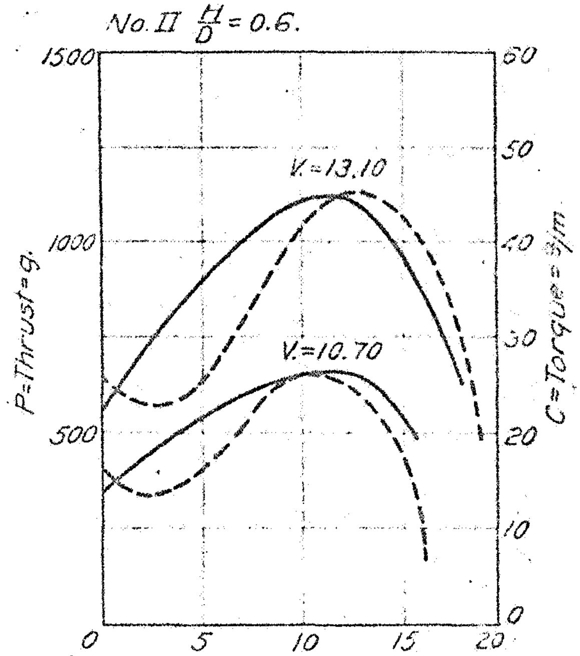

Fig. 2

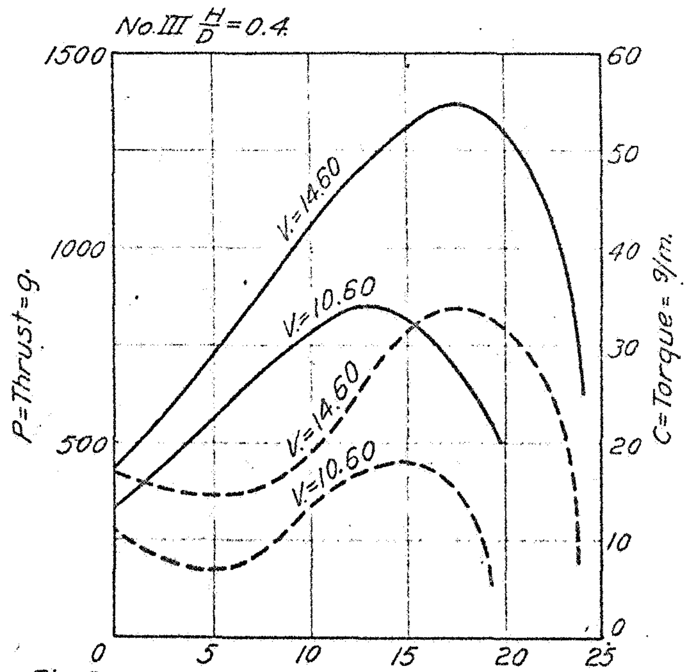

Fig. 3

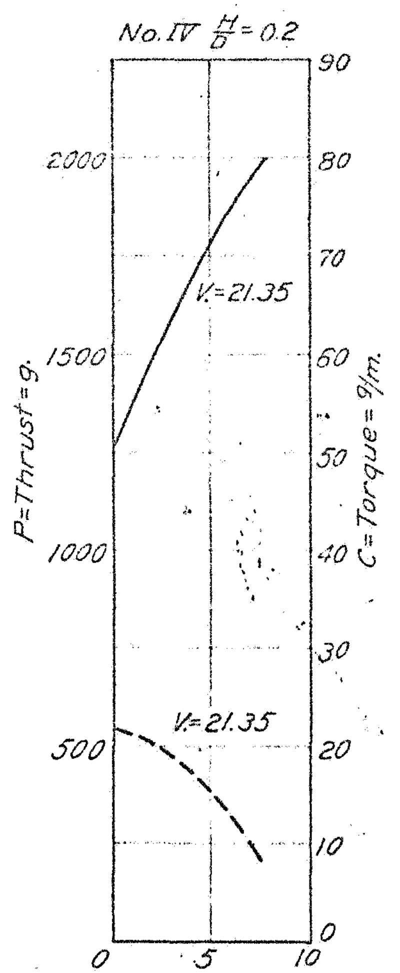

Fig. 4